

Supplementary Information

The role of nano-perovskite in the negligible thorium release in seawater from Greek bauxite residue (red mud)

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1. Supplementary Figures (14)

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Materials and Methods

Samples. The bauxite residue / BR (red mud) samples were supplied by the “Aluminium of Greece S.A.” alumina plant at Agios Nikolaos (Antikyra, Gulf of Corinth, central Greece). The Company manages BR through the installation of four filter presses, disposing its final dewatered metallurgical residue (so-called “red mud”) onto a special configured area inside its plant. The bauxite residue, used in this study, consisted of composite sample, which was created by taking the appropriate number of specimens ($n=10$) and using standard mixing procedures and sample splitters. Moreover, basic parent material (bauxite) samples ($n=16$), used in the present study for reasons of comparison, were collected from underground mining sites at the Parnassos-Ghiona, which is an active mining area of the three Greek mining companies (“Aluminium of Greece S.A.” and its subsidiary “Delphi-Distomon S.A.”, “S&B Industrial Minerals S.A.” that has been recently consolidated by “Imerys S.A.”, and “ELMIN Hellenic Mining Enterprises S.A.”), exploiting bauxite from the Parnassos-Ghiona area (Central Greece). Greek industrial bauxites actually represent the typical low-grade (i.e., Fe-rich; diasporic & boehmitic; red-brown in color) and the high-grade (i.e., Fe-depleted; diasporic; white-grey in color) exploitable samples. It is worth noting that, except for Greek karst-type bauxite, which is the major part of the parent material that “Aluminium of Greece S.A.” uses at its industrial plant, the company also imports a small proportion of tropic bauxite for its needs, in order to be used as a mixture of Al-ores for its alumina production. On this basis, since the major part of parent material does consist of Greek bauxites, we strongly claim that karst-type bauxites from Parnassos-Ghiona active mining area represent the basic parent material of the present work.

Powder X-ray Diffraction (PXRD) and Bulk Chemical Analyses (WDXRF and ICP-OES/MS). The PXRD characterization of the raw, seawater-leached and acetic acid-leached BR sample was carried out using a Siemens D5005 (currently Bruker AXS) diffractometer with $\text{CuK}\alpha$ radiation ($\lambda = 1.54 \text{ \AA}$) at an accelerating voltage of 40 kV. Along with the major and trace element chemical analysis that were performed at the PANalytical B.V. laboratories (using a PANalytical Axios^{max} WDXRF spectrometer), complementary analyses were also performed using a Perkin Elmer ICP-OES and a Perkin Elmer Sciex Elan 9000 ICP-MS spectrometer following a $\text{LiBO}_2/\text{LiB}_4\text{O}_7$ fusion and HNO_3 digestion of a 0.2 g sample. In addition, a separate 0.5 g split was digested in a $\text{HNO}_3:\text{HCl}$ mixture (1:3) and analyzed by ICP-MS for precious and base metals.

High-Resolution (HR) Gamma-Ray Spectroscopy. HR γ -ray spectra of BR and the bauxite samples were collected using a Canberra high-purity germanium (HPGe) detector. Spectra analysis resulted in the natural radioactivity levels and total dose rate.

Seawater and Acid-Leaching Experiments (SF-ICP-MS). The bauxite residue / BR (red mud) used in the leaching experiments is a composite sample which was created by taking the appropriate number of specimens ($n=10$), using standard mixing procedures and sample splitters. Simultaneously, similar leaching tests on Greek industrial bauxites were also carried out for comparison. For this purpose, two composite samples were also created to be used at leaching experiments, too. The bauxite composited samples, which are obtained from bauxite mines of “Aluminium of Greece S.A.” and its subsidiary “Delphi-Distomon S.A.”, represent both the typical low-grade (i.e., Fe-rich; diasporic & boehmitic; red-brown in color) and high-grade (i.e., Fe-depleted; diasporic; white-grey in color) karst-type bauxites from the Parnassos-Ghiona active mining area (central Greece). On a first step, powder from the BR, as well as from both the karst-type of bauxites (typically between ~ 10 and 100 mg; details are given in **Supplementary Table S1**) were weighted in zinser vials, which were then filled with 20 mL of the leaching solution (i.e., seawater or concentrated acetic acid). In addition, two experimental blank runs (only seawater and concentrated acetic acid) were also prepared in the same way using zinser vials filled with 20 mL of the particular solution. Sampling of the experimental, as well as the blank solutions, was performed at certain periods of time after the start of the leaching procedure (after 2 weeks, 1 month, 2 months, 3 months, 5 months, 7 months, 10 months, 12 months). 1 mL was taken from each vial and filtered with a syringe filter to remove particles. 500 μ L of the filtered leachate was then further diluted using 2 vol% HNO_3 (prepared from concentrated Merck ultrapure HNO_3 and deionized water with a resistance of 18 $\text{m}\Omega$) to a total of 5 mL. The concentrations of trace elements, including actinides, HFSE and REEs, in the leachates were determined using a SF-ICP-MS spectrometer (Thermo Scientific Element 2/XR). Lanthanides and As were measured in high resolution mode ($m/\Delta m = 10,000$), whereas other elements such as Cr, and V were measured in medium resolution ($m/\Delta m = 4,000$) or in case of Ta, Y, Th, and Pb in low-resolution mode ($m/\Delta m = 300$). Rhodium was added to the solutions and used as an internal standard (final Rh concentration was 1 ng g^{-1}). Plasma parameters and sample uptake conditions were optimized at the beginning of each instrumental session to achieve optimal signal stability and maximum sensitivity at low oxide ratios. Typical instrumental parameters and measured isotopes are listed in **Supplementary Table S2**. Calibrations were generally performed with adjusted solutions using acetic acid and Mediterranean seawater for matrix matching. The accuracy of the measurements was verified with various water reference materials (TM26.3 and SPS-SW1), which were also adjusted with Mediterranean seawater and acetic acid for matrix matching. Since the water reference materials are not certified for Ta a diluted matrix matched reference solution of BHVO-1 (rock reference standard material) was used. All certified values could be reproduced throughout the measurements except for Dy, which is therefore not listed in **Supplementary Table S2**. The analyzed reference material solutions yielded consistently higher Dy concentrations due to unidentified spectral interferences.

Results and Discussion

PXRD study. According to the PXRD patterns (**Supplementary Fig. S1**) the investigated Greek BR contains hematite ($\alpha\text{-Fe}_2\text{O}_3$), calcite (CaCO_3), ALOOH polymorphs (gibbsite: $\text{Al}(\text{OH})_3$; diaspora; $\alpha\text{-AlOOH}$) as well as Na-Ca-Al-silicate-carbonate and Ca-Al-hydroxysilicate phases (cancrinite- and “hydrogarnet”-type phases). “Hydrogarnet” may correspond to katoite¹ ($\text{Ca}_3\text{Al}_2(\text{SiO}_4)_{3-x}(\text{OH})_{4x}$, $x=1.5\text{--}3.0$ or $\{\text{Ca}_3\}[\text{Al}_2](\square_3)(\text{OH})_{12}$), on the basis of previous measurements². It should be noted that the same crystalline phases have also been detected in BR from Ajka alumina plant accident³. The same phases have also been detected in the case of seawater-treated samples. On the other hand, carbonate minerals (at least calcite), and also Ca-Al-hydroxysilicate phases, are practically absent in BR samples leached with acetic acid solutions. There is also a severe decrease in the intensity of cancrinite ($\text{Na}_6\text{Ca}_2\text{Al}_6\text{Si}_6\text{O}_{24}(\text{CO}_3)_2$) peaks, in accordance with previous observations for acid-treated BR, by Liang et al. (2014)⁴. Moreover, distinct peaks of anatase, quartz and phyllosilicates/clay-like phases are revealed in the PXRD patterns of the acetic-acid leached BR. Therefore, Fe-oxides, Ti-oxides, ALOOH-polymorphs and clay-like phases are resistant in seawater and acetic acid solutions^{4,5}.

EELS Measurements. The Ti $L_{2,3}$, Ca $L_{2,3}$ and O K -edge EEL spectral data (**Supplementary Fig. S9**) indicate that the phase found in Greek BR has rather similar spectral characteristics with CTO studied by Calvert et al. (2006)⁶. The comparison of the nano-perovskite Ti $L_{2,3}$ and O K -edges with CTO phases from literature has revealed that the Ti $L_{2,3}$ -edges show structural similarities in terms of the observed crystal field effects⁶. In particular, the Ti $L_{2,3}$ -edges show a well defined crystal field splitting of both the L_3 (A_1 and A_2 peaks) and L_2 edges (B_1 and B_2 peaks), very similar to the splitting phenomenon for reference CaTiO_3 perovskite phase⁶. On the other hand, the splitting of L_2 edge, into the B_1 and B_2 peaks seems to be less well-defined than that of L_3 . The splitting can be assigned to a slight distortion of the TiO_6 octahedra from tilting, due to the presence of Ca and Na, and/or changes in the degree of covalence in Ti-O bonding in the studied phase. It can also be assumed that BR nano-perovskite contains only Ti^{4+} , having almost the same EEL spectrum to that of CTO from literature⁶. Furthermore, the O K -edges can be separated into the $A_{\parallel}$ and $A_{\perp}$ components, corresponding to the A peaks that commonly appear within the 5-6 eV above the edge threshold; this is followed by another B peak, corresponding thus to B peaks that usually appear 10 eV above the threshold. The difference is the small and narrow A_2 peak, between the A_1 and A^* peaks of Calvert's reference CTOs⁶, which is not obvious in our O K -edge spectrum, maybe due to the presence of the stronger $A_{\parallel}$ component within a

few electron volt or due to poor signal-to-noise ratio in the spectrum. The broader A_{II} component of our novel CTO is close to the intensity of sharper A_I component, giving assumption of a higher energy-loss shoulder. The broad B peak resembles to that of A_{II} peak and does not show any splitting phenomenon, which agrees to that of Calvert's reference CTOs⁶. In general, the shape of the O K -edge spectrum is in agreement. Taking into account the above, one may say that A components of the O K -edge EEL spectrum are attributed to the hybridization of the O 2p with Ti and Ca 3d-like states, while the B peak is due to hybridization of O 2p with TM 4s- and continuum-like states, as mentioned for CTO phases⁶. Moreover, according to the Na K -edge EEL data, there is no doubt that our nano-perovskite also contains Na, which has been previously confirmed by STEM-EDS spectra (**Fig. 3**) and, additionally, by the quantitative EDS elemental maps (see image **d** of **Fig. 3**). Furthermore, the absence of N (401 eV) was confirmed as well, which “artificially” has been detected at 452 eV by STEM-EDS (see image **b** of **Fig. 3**). Actually, this “artificial” EDS N peak is attributed to Ti $L\alpha$.

Supplementary Table S1: Details of leaching experiments with regard to the studied bauxite residue / BR (red mud) and Greek typical low grade (i.e., Fe-rich; diasporic and boehmitic; red-brown in color) and high grade (i.e., Fe-depleted; diasporic; white-grey in color) bauxite samples.

Starting Date	Treatment Solution	Bauxite residue (red mud) & bauxite samples		Sample Weight (mg)	Amount of Solution (mL)	
		Type	Code			
6.11.2012	Concentrated Acetic Acid	Red Mud		RM-AC-1	102.4	20
6.11.2012				RM-AC-2	12.5	20
6.11.2012		Greek Bauxite	High Grade	HGB-AC-1	99.1	20
6.11.2012				HGB-AC-2	11.8	20
6.11.2012			Low Grade	LGB-AC-1	104.2	20
6.11.2012				LGB-AC-2	9.2	20
6.11.2012	Mediterranean seawater (Gulf of Corinth – Greece)	Red Mud		RM-SW-1	98.9	20
6.11.2012				RM-SW-2	18.7	20
6.11.2012				RM-SW-3	9.1	20
6.11.2012		Greek Bauxite	High Grade	HGB-SW-1	102.7	20
6.11.2012				HGB-SW-2	20.9	20
6.11.2012				HGB-SW-3	10.8	20
6.11.2012			Low Grade	LGB-SW-1	99.2	20
6.11.2012				LGB-SW-2	19.9	20
6.11.2012				LGB-SW-3	9.9	20

Supplementary Table S2: Instrumental parameters for SF-ICP-MS measurements.

<i>Instrumental settings</i>	
Forward Power (W)	1250
Cooling gas flow rate (L min ⁻¹)	16
Auxiliary gas flow rate (L min ⁻¹)	0.9
Sample gas flow rate (L min ⁻¹)	1.195
Cones	Nickel
<i>Sample introduction</i>	
Nebulizer	PFA micro-concentric
Spray chamber	PC ³ -System
<i>Data acquisition</i>	
Monitored masses	²³² Th, ²⁰⁷ Pb, ²⁰⁸ Pb, ⁸⁹ Y, ¹⁸¹ Ta (low resolution mode) ⁵³ Cr, ⁵¹ V, ¹¹³ Cd (medium resolution mode) ¹³⁹ La, ¹⁴⁰ Ce, ¹⁴¹ Pr, ¹⁴⁶ Nd, ¹⁴⁹ Sm, ¹⁵³ Eu, ¹⁵⁸ Gd, Dy, ¹⁵⁹ Tb, ¹⁶⁵ Ho, ¹⁶⁷ Er, ¹⁶⁹ Tm, ¹⁷³ Yb, ¹⁷⁵ Lu, ⁷⁵ As (high resolution mode)

Supplementary Table S3: Major and trace element concentrations in the studied bauxite residue (BR) mainly according to the WDXRF and, complementary, to the ICP-OES/MS measurements. Commonly, the elements in the light REE (LREE) and heavy REE (HREE) groups are arbitrary defined⁷⁻⁹.

Fe₂O₃	(wt.%)	41.27	Cr	(μg g ⁻¹)	2403	Y	(μg g ⁻¹)	97	Gd	(μg g ⁻¹)	16	Br	(μg g ⁻¹)	4
Al₂O₃	(wt.%)	15.90	Zr	(μg g ⁻¹)	1188	Nd	(μg g ⁻¹)	92	Yb	(μg g ⁻¹)	15	Tb	(μg g ⁻¹)	3
CaO	(wt.%)	12.99	V	(μg g ⁻¹)	1081	Zn	(μg g ⁻¹)	58	U	(μg g ⁻¹)	15	Rb	(μg g ⁻¹)	3
SiO₂	(wt.%)	6.12	Ni	(μg g ⁻¹)	902	Cu	(μg g ⁻¹)	54	Sm	(μg g ⁻¹)	15	Lu	(μg g ⁻¹)	2
TiO₂	(wt.%)	5.78	Ce	(μg g ⁻¹)	439	Co	(μg g ⁻¹)	40	Te	(μg g ⁻¹)	13	Tm	(μg g ⁻¹)	2
Na₂O	(wt.%)	2.86	Ba	(μg g ⁻¹)	234	Ga	(μg g ⁻¹)	39	Er	(μg g ⁻¹)	13	Se	(μg g ⁻¹)	2
Total C	(wt.%)	1.53	As	(μg g ⁻¹)	164	Hf	(μg g ⁻¹)	30	Cs	(μg g ⁻¹)	13	Cd	(μg g ⁻¹)	0.5
LOI	(wt.%)	13.6	Sr	(μg g ⁻¹)	131	W	(μg g ⁻¹)	30	Ta	(μg g ⁻¹)	8	Ag	(μg g ⁻¹)	0.3
MgO	(wt.%)	0.21	Pb	(μg g ⁻¹)	120	Sb	(μg g ⁻¹)	26	Ge	(μg g ⁻¹)	8	Hg	(ng g ⁻¹)	40
P₂O₅	(wt.%)	0.12	La	(μg g ⁻¹)	115	Pr	(μg g ⁻¹)	24	Bi	(μg g ⁻¹)	7	Au	(ng g ⁻¹)	bdl
K₂O	(wt.%)	0.08	Sc	(μg g ⁻¹)	114	Dy	(μg g ⁻¹)	20	Be	(μg g ⁻¹)	5	ΣLREE*¹	(μg g ⁻¹)	704
Total S	(wt.%)	0.07	Th	(μg g ⁻¹)	111	Sn	(μg g ⁻¹)	19	Ho	(μg g ⁻¹)	4	ΣHREE*²	(μg g ⁻¹)	157
MnO	(wt.%)	0.03	Nb	(μg g ⁻¹)	106	Mo	(μg g ⁻¹)	17	Eu	(μg g ⁻¹)	4	ΣREE*³	(μg g ⁻¹)	976

*¹ ΣLREE group includes the lanthanide elements from La through Gd^{8,9}.

*² ΣHREE group includes the lanthanide elements from Tb through Lu, including Y^{8,9}.

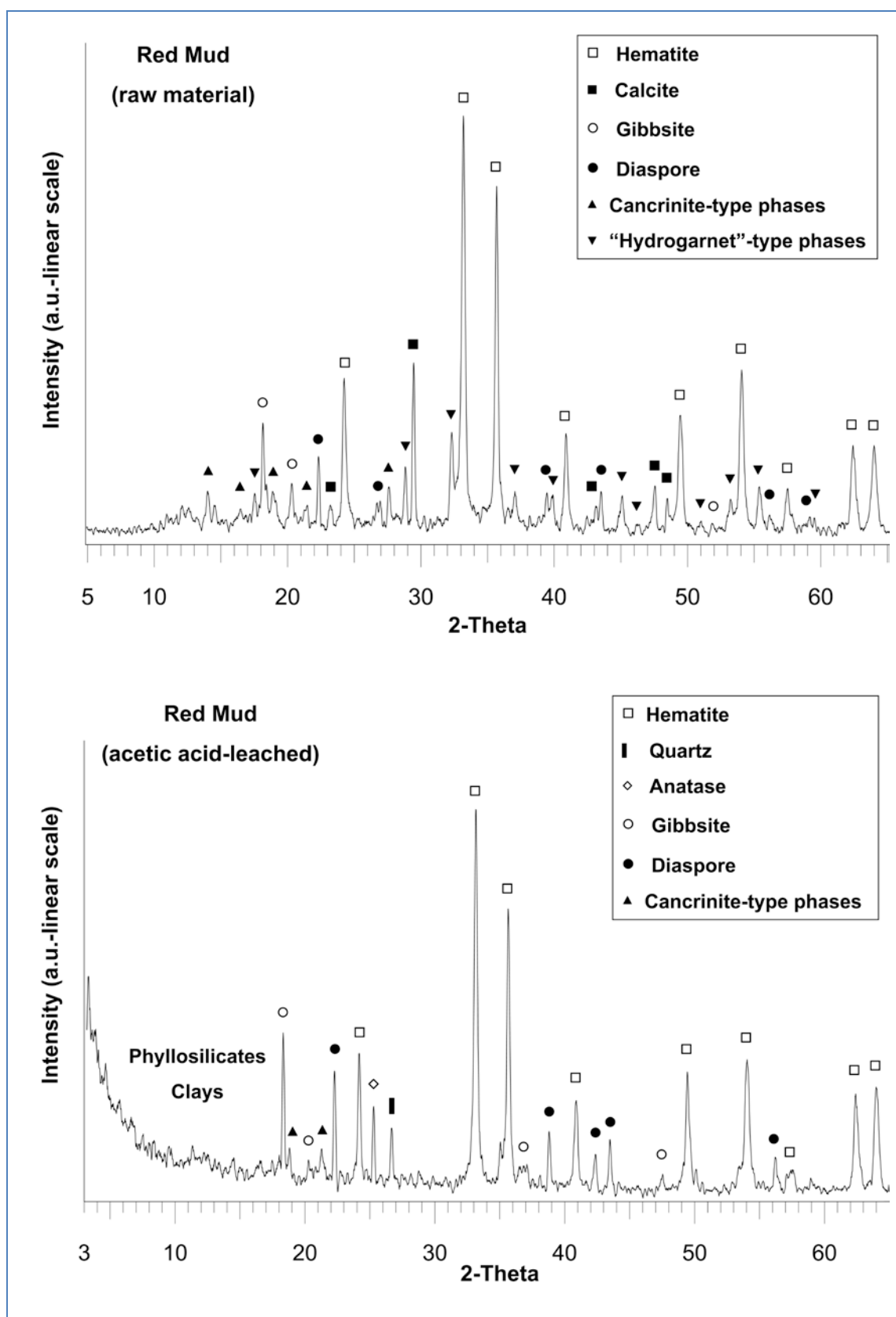
*³ ΣREE group comprises of the 15 lanthanide elements including Sc, and Y^{8,9}.

Supplementary Table S4: Natural radionuclides (Bq kg⁻¹) and total dose rate (nGy h⁻¹) of the studied bauxite residue / BR (red mud) and representative Greek bauxites ($n=10$)¹⁰ compared with relevant values from literature^{2,11-25}.

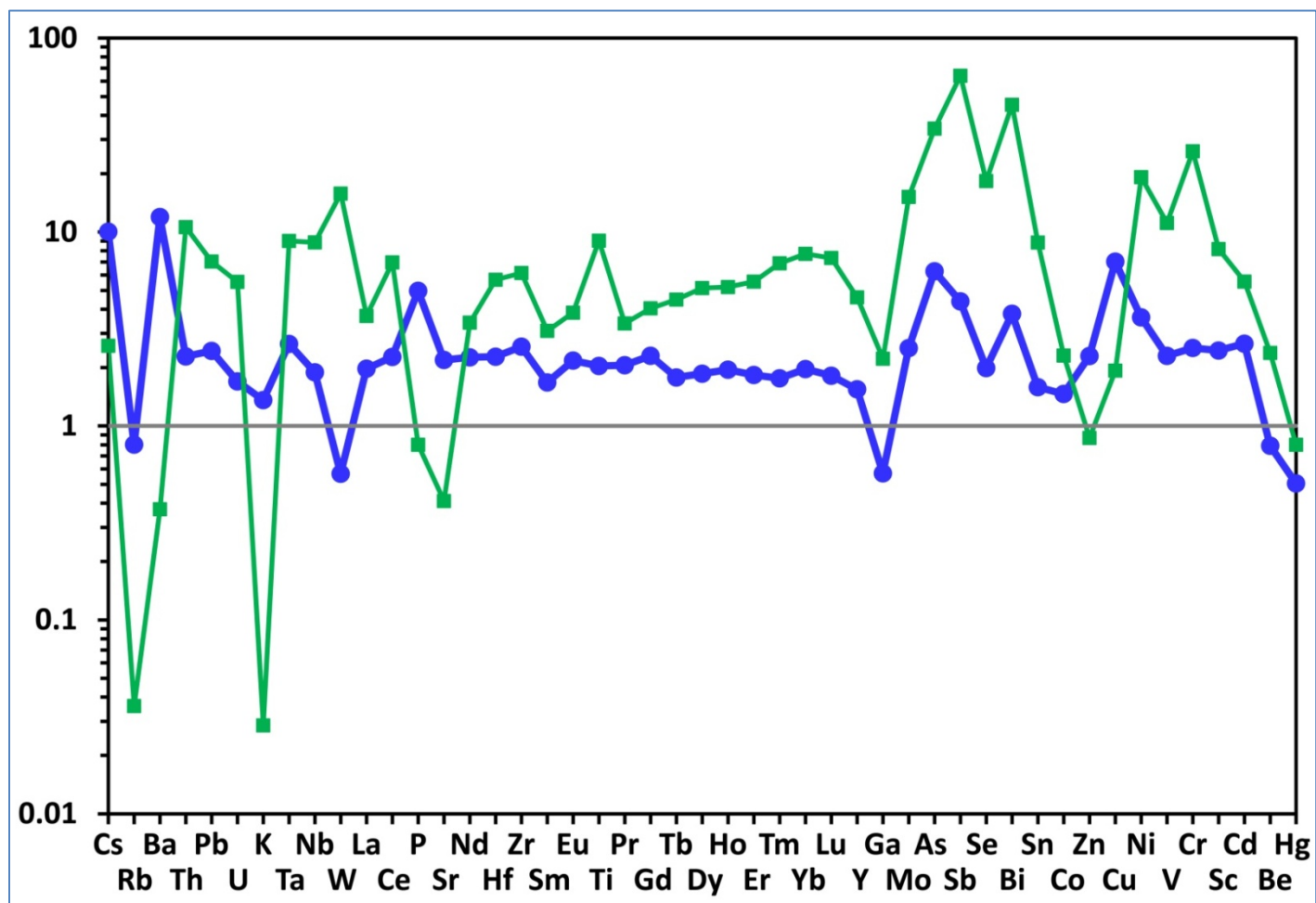
GREEK BAUXITES: Radioactivity (Bq kg ⁻¹) & Total Dose Rate (nGy h ⁻¹)						
<u>Greek bauxites (present study)</u>		²³² Th	²³⁸ U	²²⁶ Ra	⁴⁰ K	¹³⁷ Cs
Sample Code	Sample Description	(due to ²²⁸ Ac)	(due to ²³⁴ Th)			Total Dose Rate
ALM0306_PL1_B1	<i>Low grade; Fe-rich; Diasporic; Red-brown</i>	192	69	138	15	0
ALM0306_PL1_B3	<i>Low grade; Fe-rich; Diasporic; Red-brown</i>	184	89	130	57	0
ELM0206_DV_B1	<i>Low grade; Fe-rich; Diasporic; Red-brown</i>	179	44	115	15	0
SAB0306_ASV	<i>Low grade; Fe-rich; Diasporic; Red-brown</i>	203	42	96	16	0
ALM0306_PL1_B2	<i>Low grade; Fe-rich; Boehmitic; Red-brown</i>	159	54	129	60	0
ELM0206_KV_B1	<i>Low grade; Fe-rich; Boehmitic; Red-brown</i>	155	27	64	109	0
ELM0206_2H1	<i>Low grade; Fe-rich; Boehmitic; Red-brown</i>	161	60	145	108	0
SAB0306_SKR	<i>Low grade; Fe-rich; Boehmitic; Red-brown</i>	166	38	83	49	0
ALM0306_PL1_BIW	<i>High grade; Fe-depleted; Diasporic; White-grey</i>	229	121	144	17	0
ALM0306_PL1_BS2	<i>High grade; Fe-depleted; Diasporic; White-grey</i>	191	118	160	12	0
Min – Max Values		155 – 229	27 – 121	64 – 160	17 – 117	0
Average Value		182	66	120	46	0
<u>Greek bauxites (previous works)</u>						
Greek bauxites ¹¹		205 – 226	143 – 248	74 – 150	28	

Supplementary Table S4: (continued)

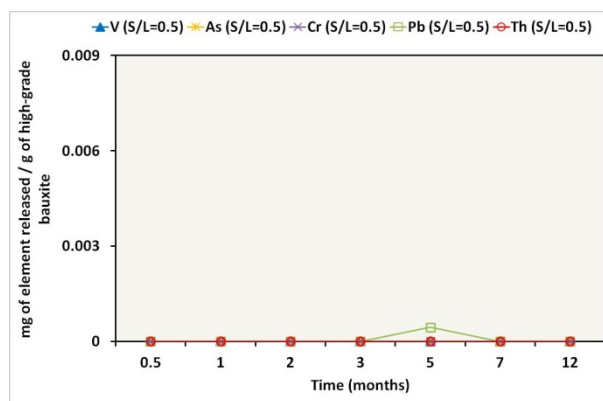
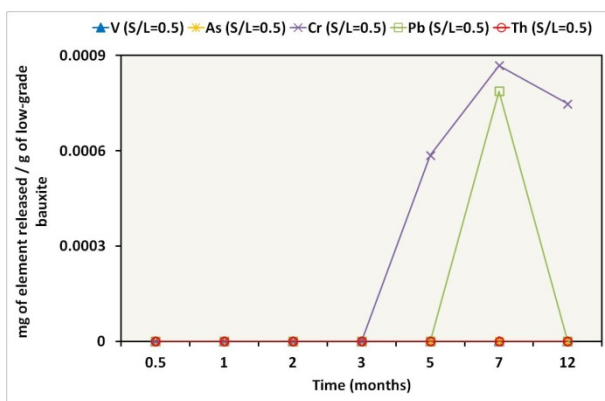
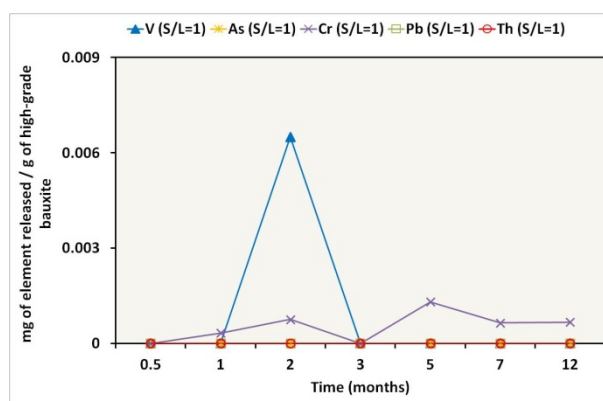
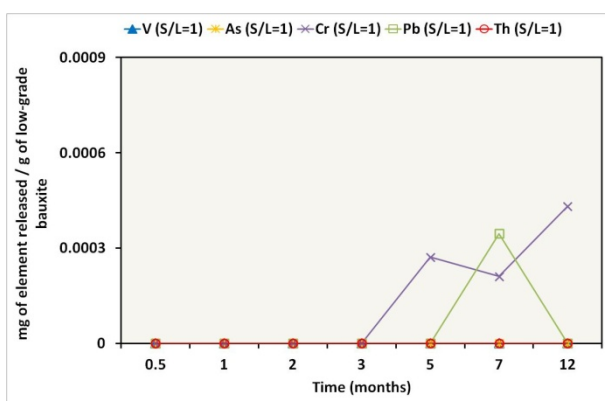
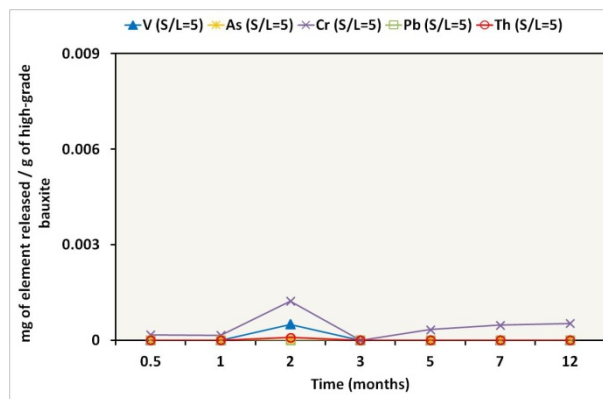
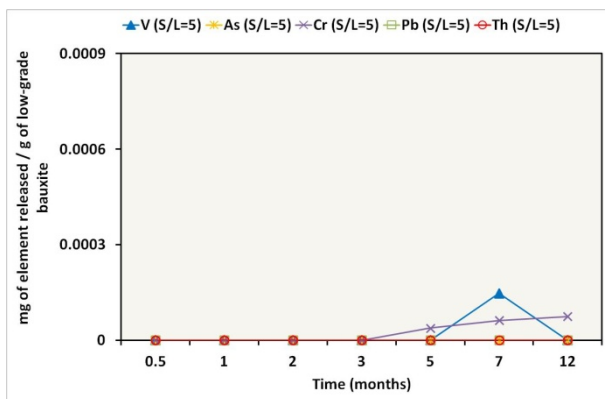
Bauxite Residue / BR (Red Mud) Radioactivity (Bq kg⁻¹) & Total Dose Rate (nGy h⁻¹)						
<u>Greece</u>						
Red Mud - Greece (present study)	355	133	171	45	0	295
Red Mud - Greece ¹¹	15 – 412	52 – 400	13 – 185	72 – 160	1 – 5	
Red Mud - Greece ²	472	149	379	21		
Red Mud - Greece ¹²	346	182	232	45		
<u>Worldwide</u>						
Red Mud - Turkey ¹³	539	218	210	112		
Red Mud - Turkey ¹⁴	342 – 357		128 – 285	94 – 110		
Red Mud - Hungary ¹⁵	219 – 392		225 – 568	5 – 101		
Red Mud - Hungary ¹⁶	285 – 380		150 – 700	5 – 101		
Red Mud - Hungary ¹⁶	87 – 545		102 – 506	47 – 212		
Red Mud - Hungary ¹⁷	640	550		250	5.5	
Red Mud - Spain ¹⁸	598	350	203	62		
Red Mud - Germany ¹⁹	183	85	122			
Red Mud - Jamaica ²⁰	328 – 350		370 – 1047	265 – 335		
Red Mud - Australia ²¹	1129		326	30		
Red Mud - Australia ²²		400	310	350		
Red Mud - Australia ²³ and refs therein	1000 – 1900	150 – 600		70 – 230		
Red Mud - China ²⁴	705	477		153		
Red Mud - China ²⁵	360 – 475		125 – 620	67 – 247		



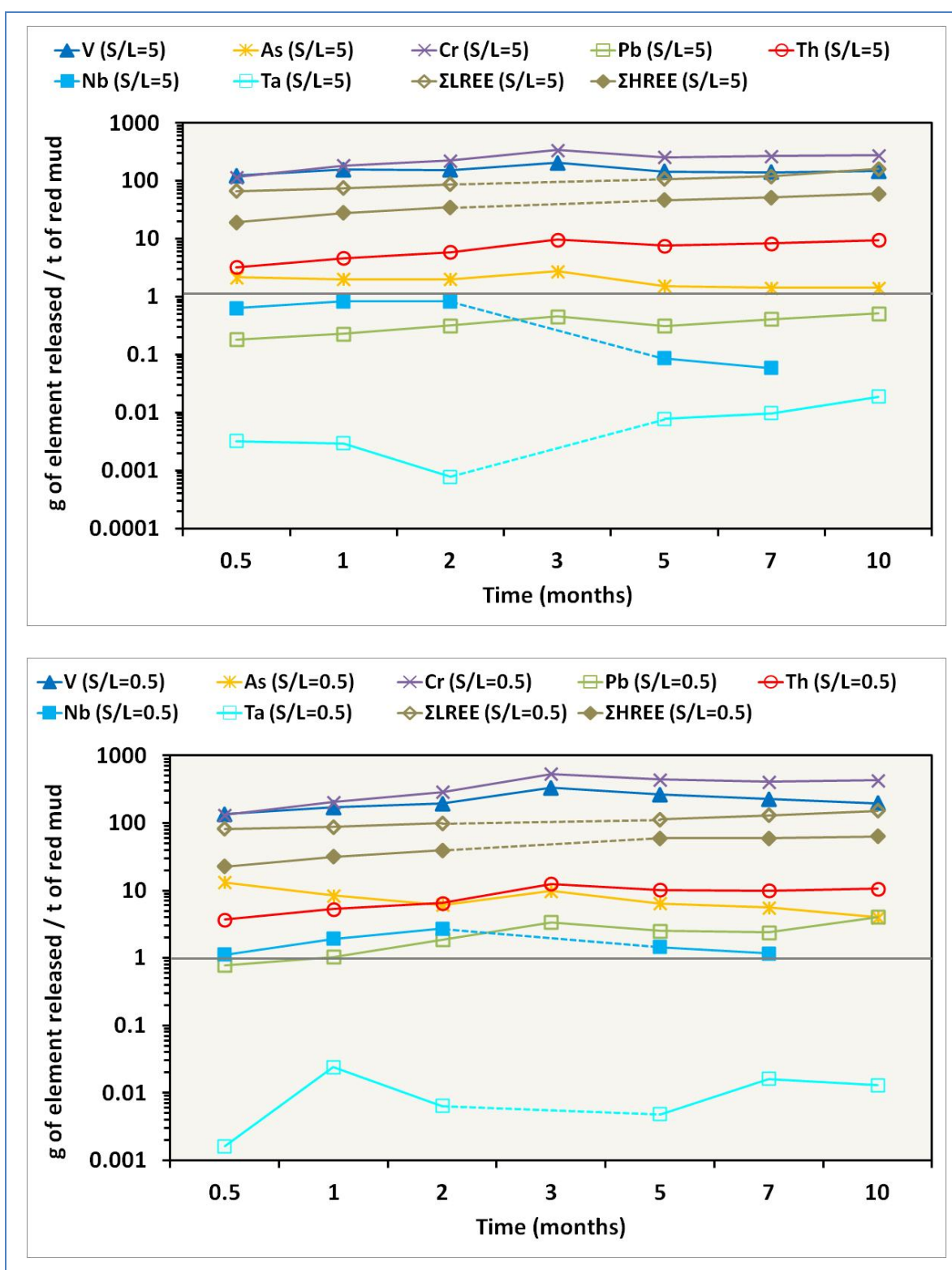
Supplementary Figure 1 | PXRD pattern of the studied bauxite residue / BR (red mud) from Greece (raw material: upper image) and the acetic acid-leached sample (lower image).



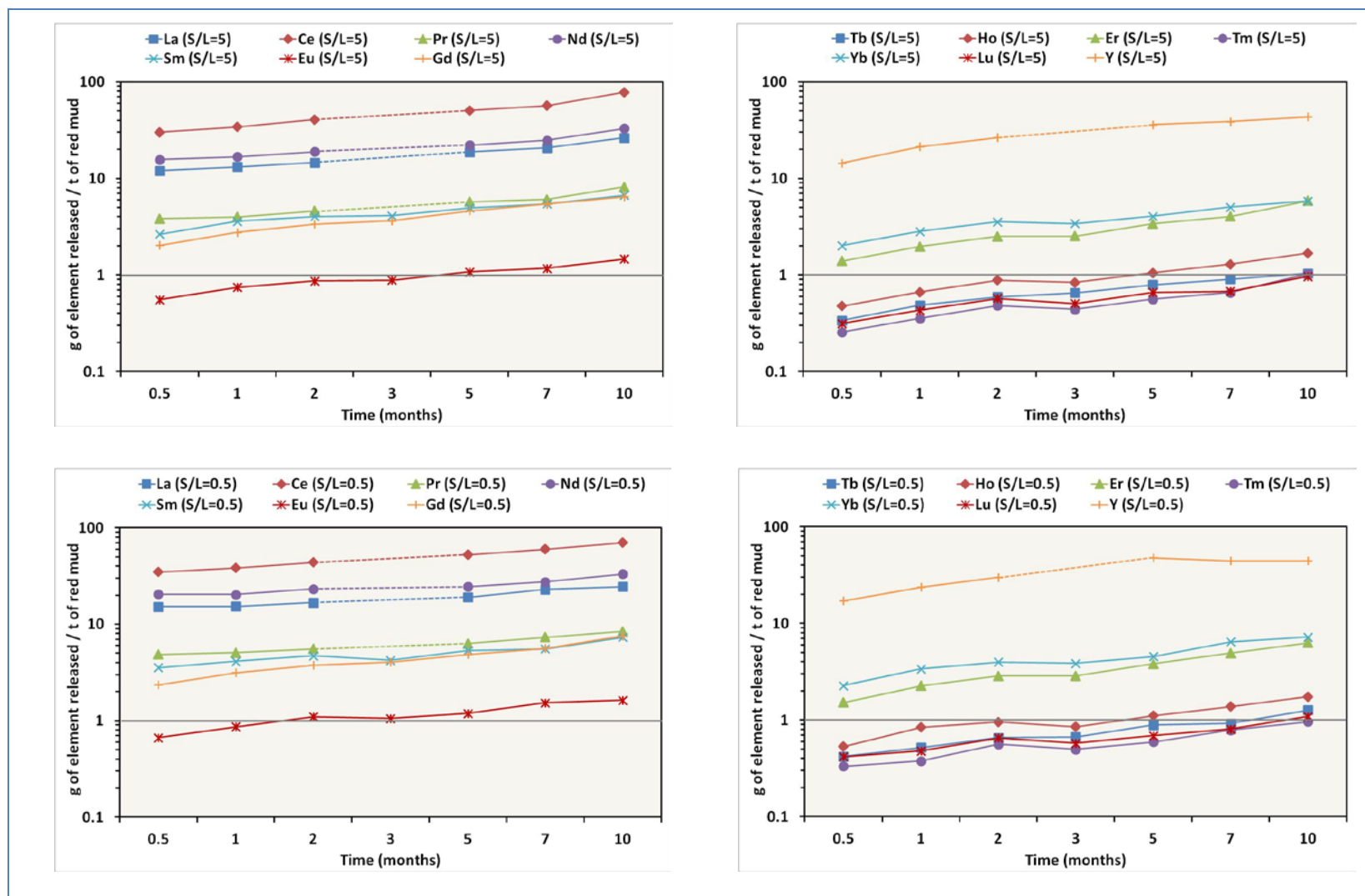
Supplementary Figure 2 | Spider diagrams of the studied bauxite residue / BR elemental content normalized: (a) to the average ($n=16$)¹⁰ of the chemical composition of Greek bauxites from the Parnassos-Ghiona area, solid blue circles; (b) to the reference values of Upper Continental Crust/UCC²⁶, solid green squares.



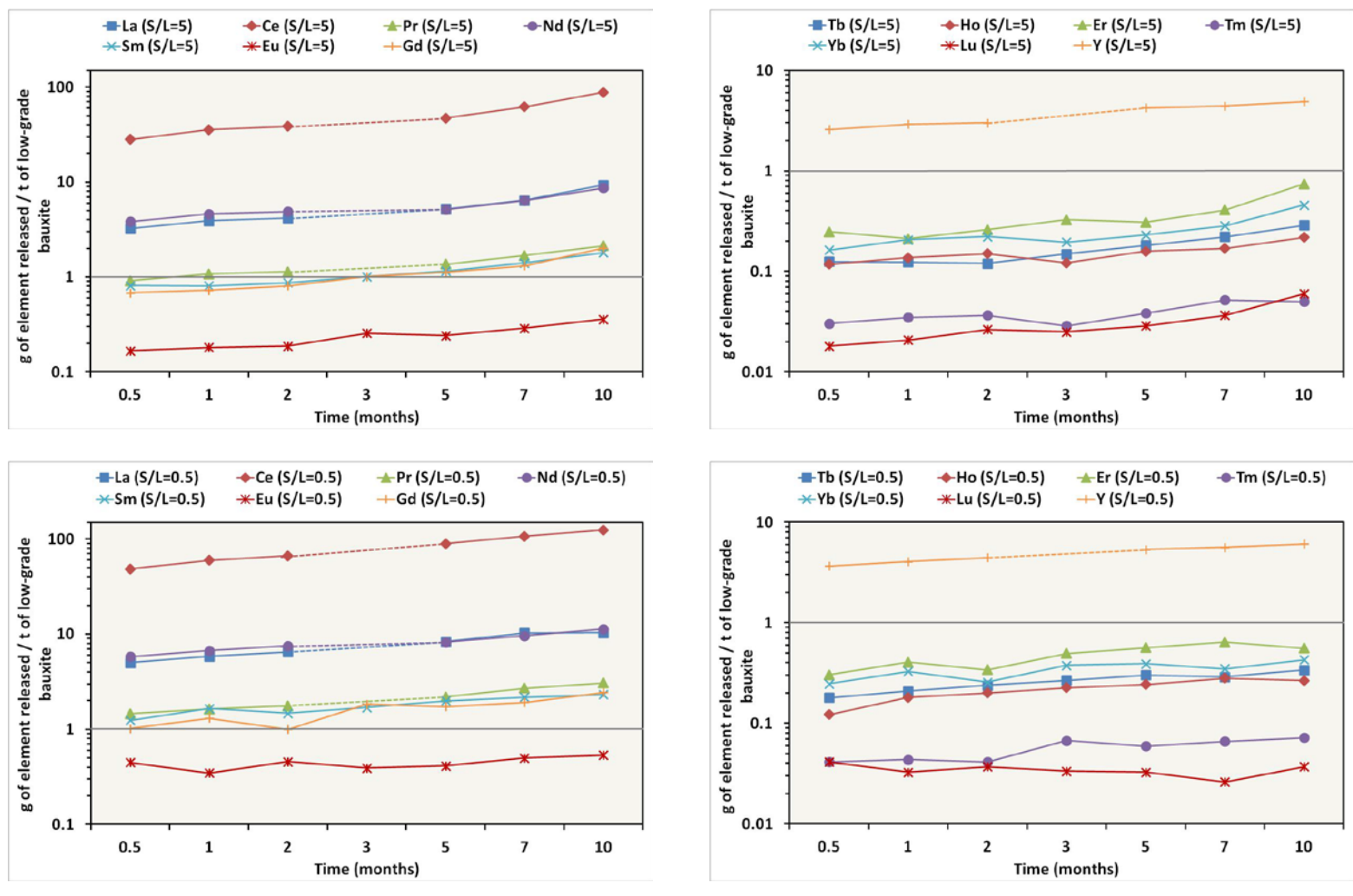
Supplementary Figure 3 | Results from leaching experiments showing the V, As, Cr, Pb, and Th negligible release from typical low-grade (left images) and high-grade (right images) Greek bauxite leached by Mediterranean seawater from Greece.



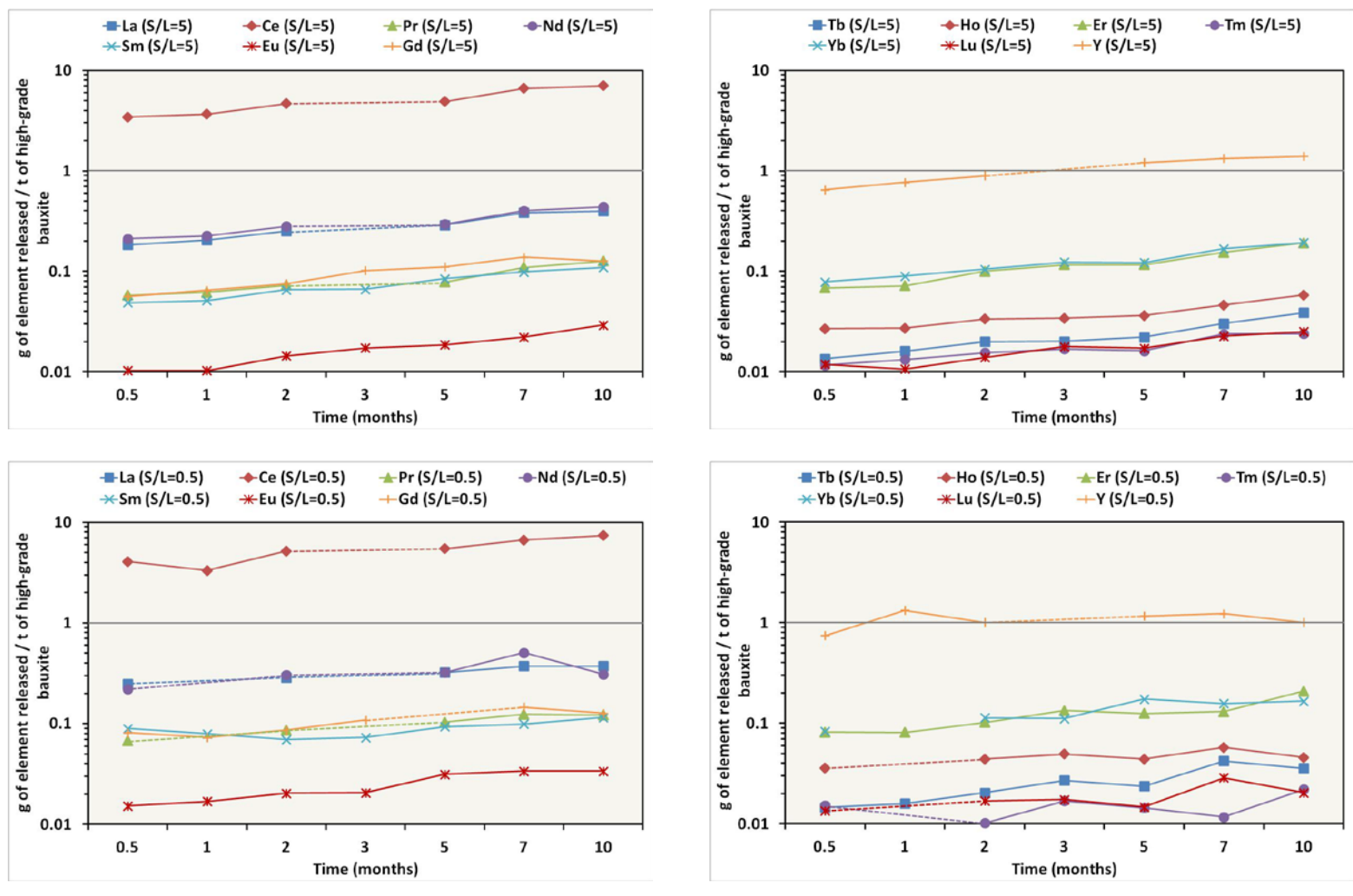
Supplementary Figure 4 | Results from leaching experiments showing the release of Σ LREE, and Σ HREE, along with with Cr, V, Th, As, Pb, Nb, and Ta from Greek bauxite residue / BR (red mud) leached by concentrated acetic acid.



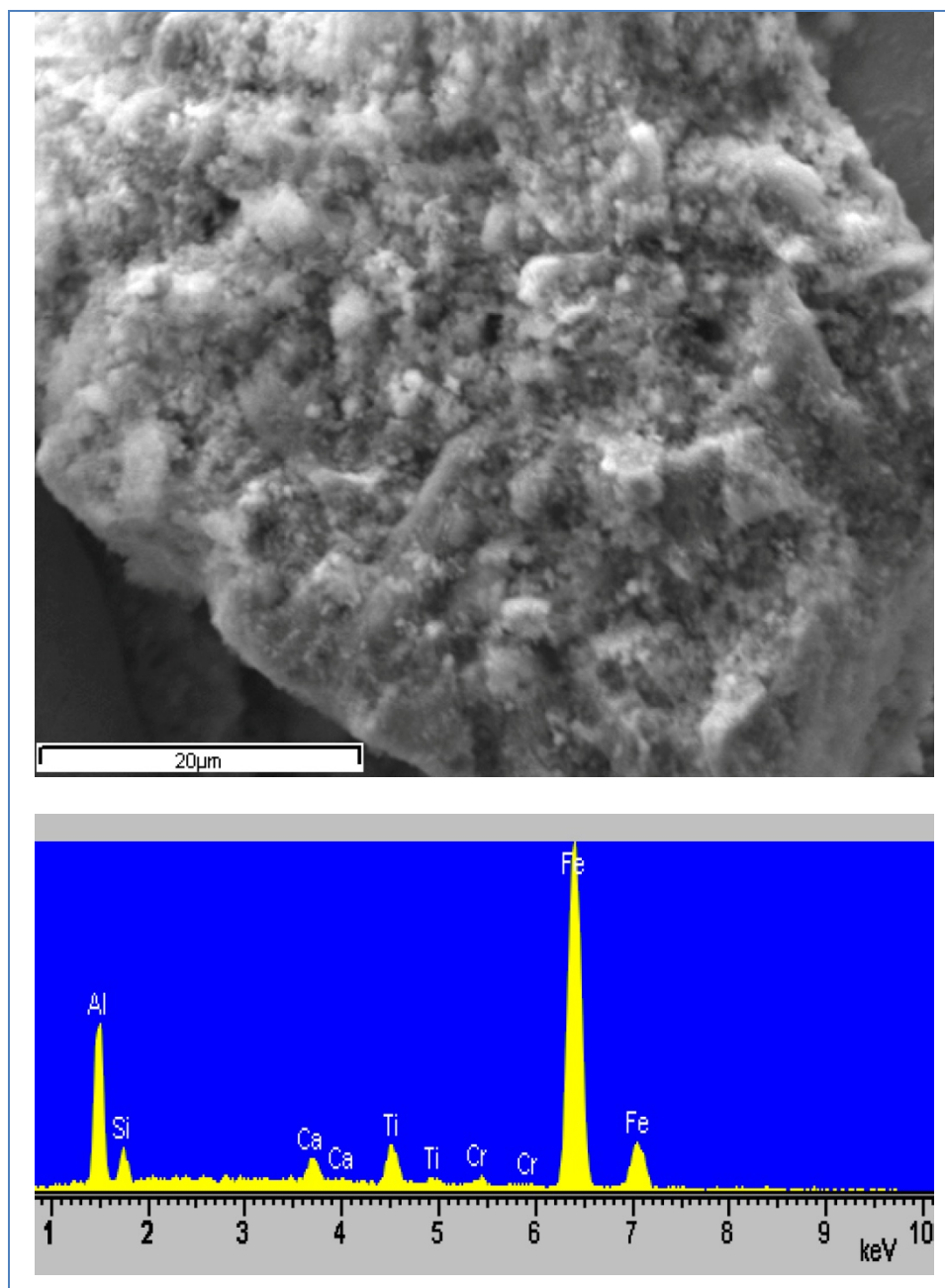
Supplementary Figure 5 | Results from leaching experiments showing the LREE (La, Ce, Pr, Nd, Sm, Eu, and Gd; left images) as well as the HREE (Tb, Ho, Er, Tm, Yb, Lu, and Y; right images) release (g) per 1 ton of Greek bauxite residue / BR (red mud) leached by concentrated acetic acid.



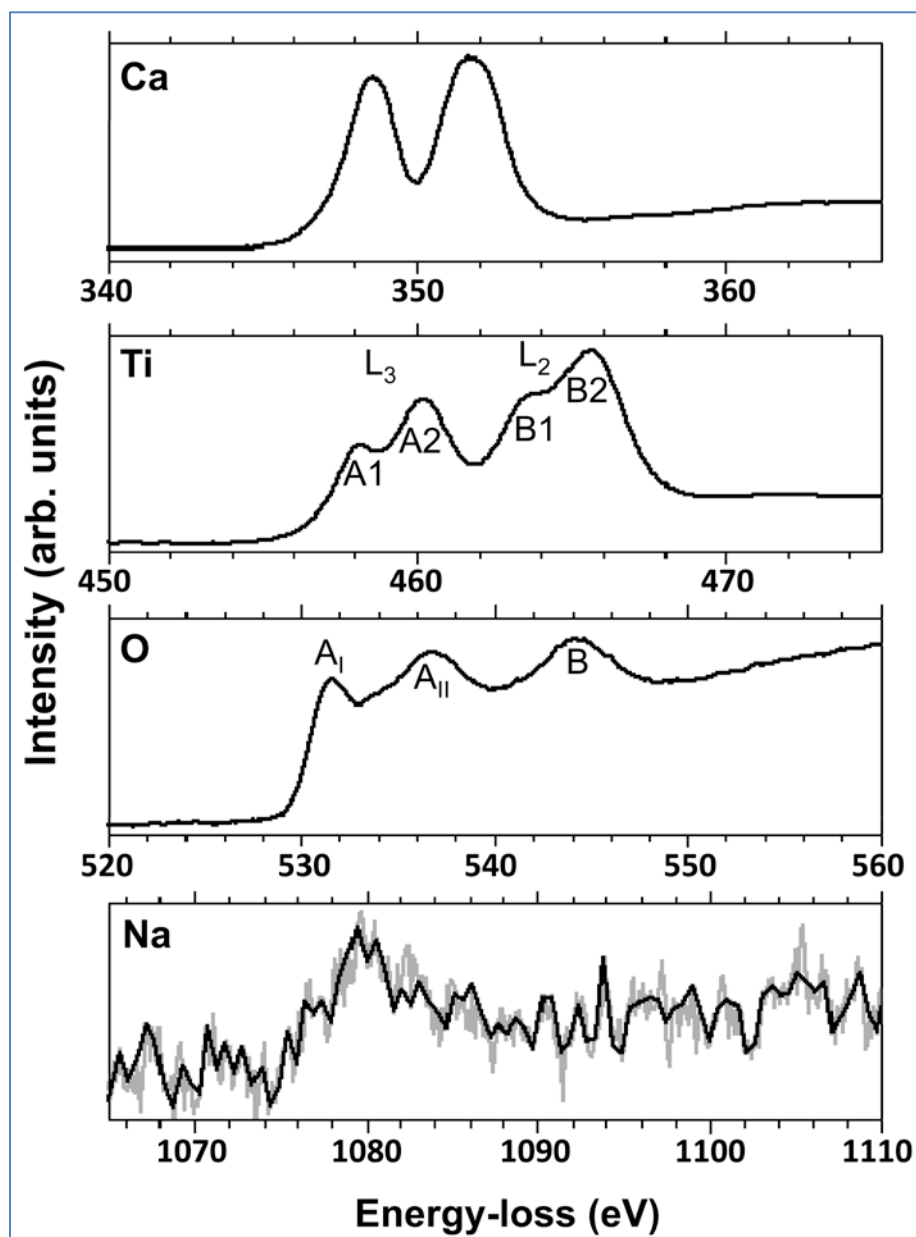
Supplementary Figure 6 | Results from leaching experiments, relative to S/L ratio effect, showing the LREE (La, Ce, Pr, Nd, Sm, Eu, and Gd; left images) as well as the HREE (Tr, Ho, Er, Tm, Yb, Lu, and Y; right images) release from Greek typical low-grade bauxites leached by concentrated acetic acid.



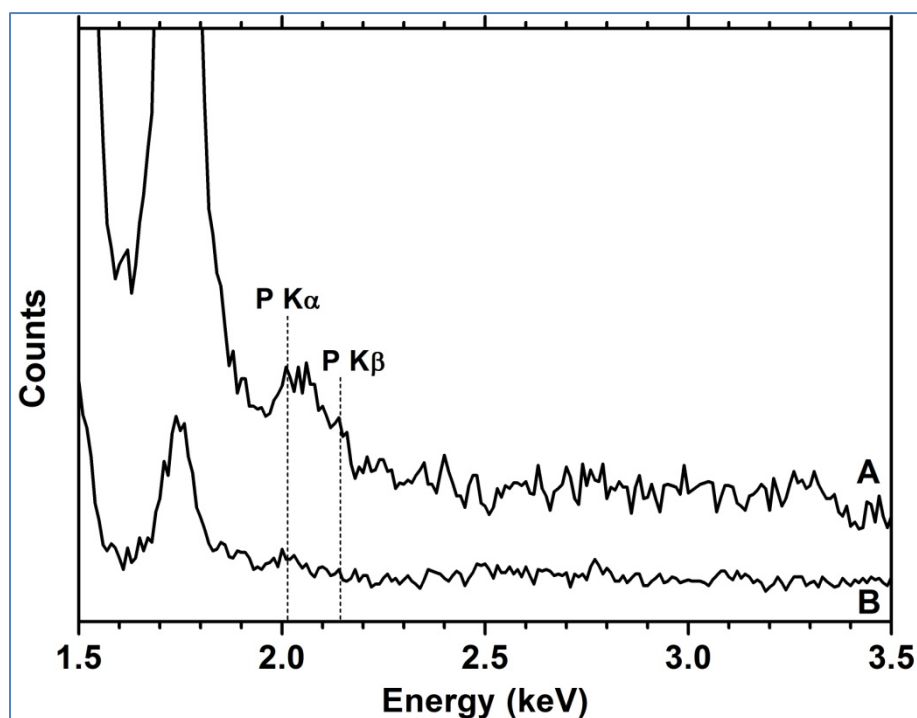
Supplementary Figure 7 | Results from leaching experiments, relative to S/L ratio effect, showing the LREE (La, Ce, Pr, Nd, Sm, Eu, and Gd; left images) as well as the HREE (Tr, Ho, Er, Tm, Yb, Lu, and Y; right images) release from Greek high-grade bauxites leached by concentrated acetic acid.



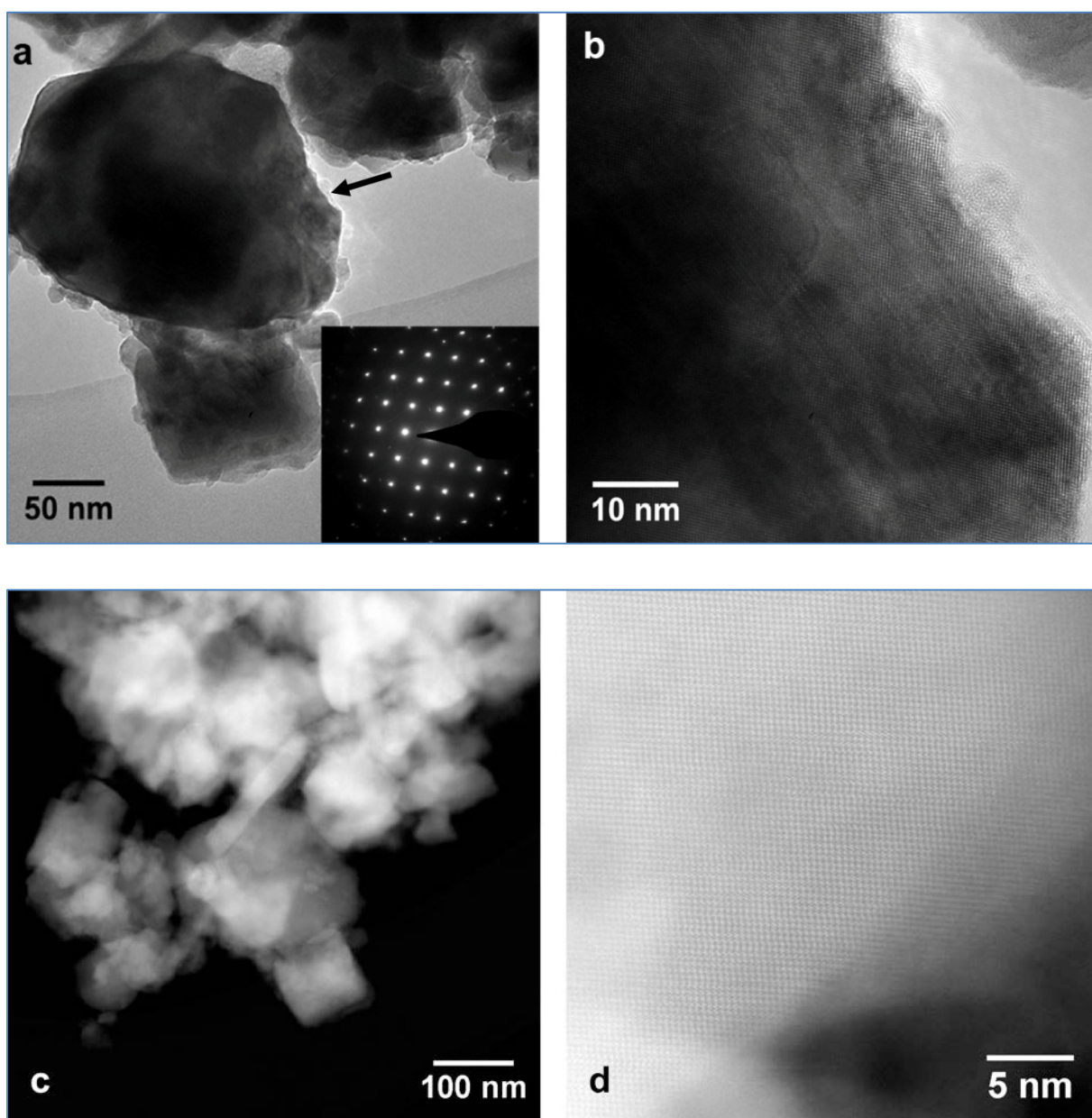
Supplementary Figure 8 | Morphology and chemical composition (major elements) of the studied bauxite residue / BR (red mud) by SEM-EDS at the microscale, after acid-leaching.



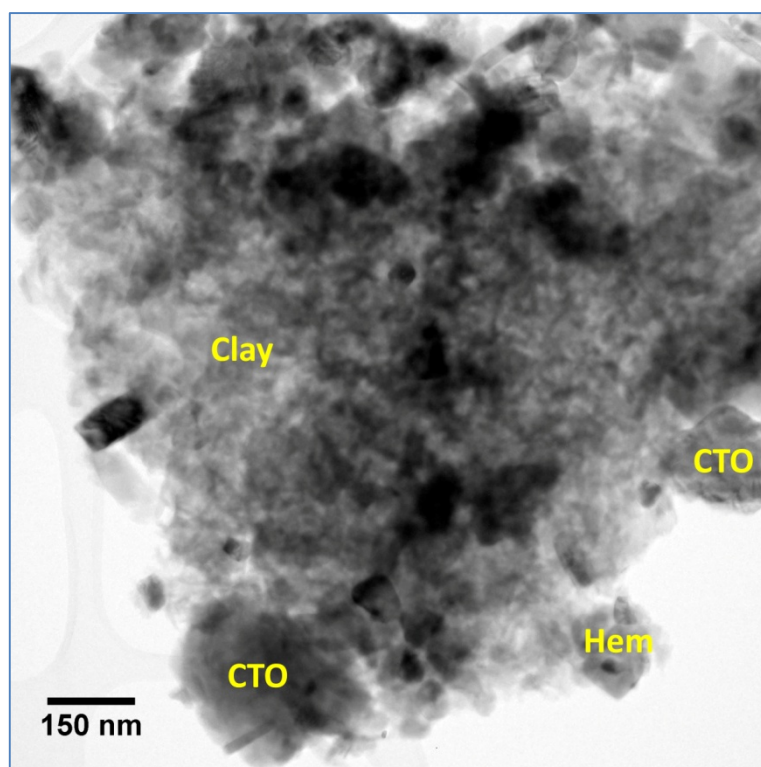
Supplementary Figure 9 | Representative Ca $L_{2,3}$ -, Ti $L_{2,3}$ -, O K- and Na K-edge EEL spectral data of the nano-perovskite in the Greek bauxite residue / BR (red mud).



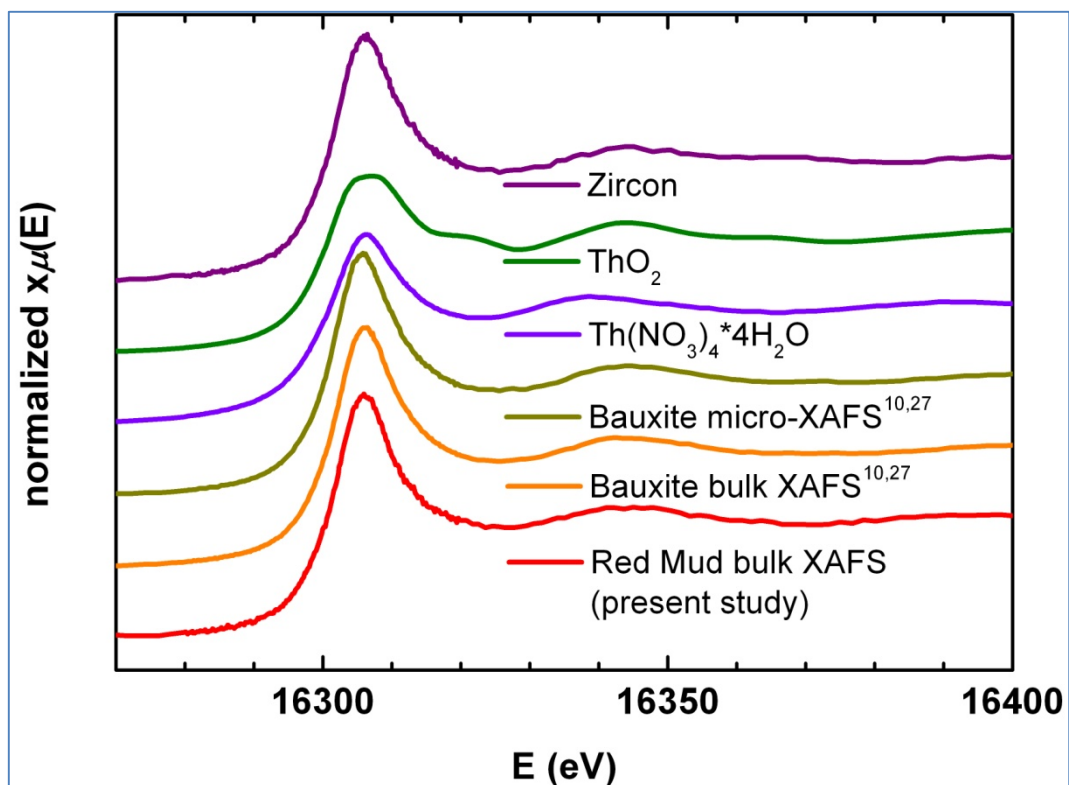
Supplementary Figure 10 | The appearance of the P K α peak (2.01 KeV) at the STEM-EDS spectrum of a Ti-containing hematite particle (**A**: hematite [211]; see also **Fig. 4**), in contrast to the absence of the P K α peak at the STEM-EDS spectrum of another Ti-containing hematite particle (**B**: hematite [241]). Both the Ti-containing hematite particles observed in the “Al-Fe-Ca-Ti-Si-Na-Cr matrix” of the studied Greek bauxite residue / BR (red mud). A small contribution from the P K β peak (2.14 KeV) at the Ti-containing hematite [211] cannot be excluded.



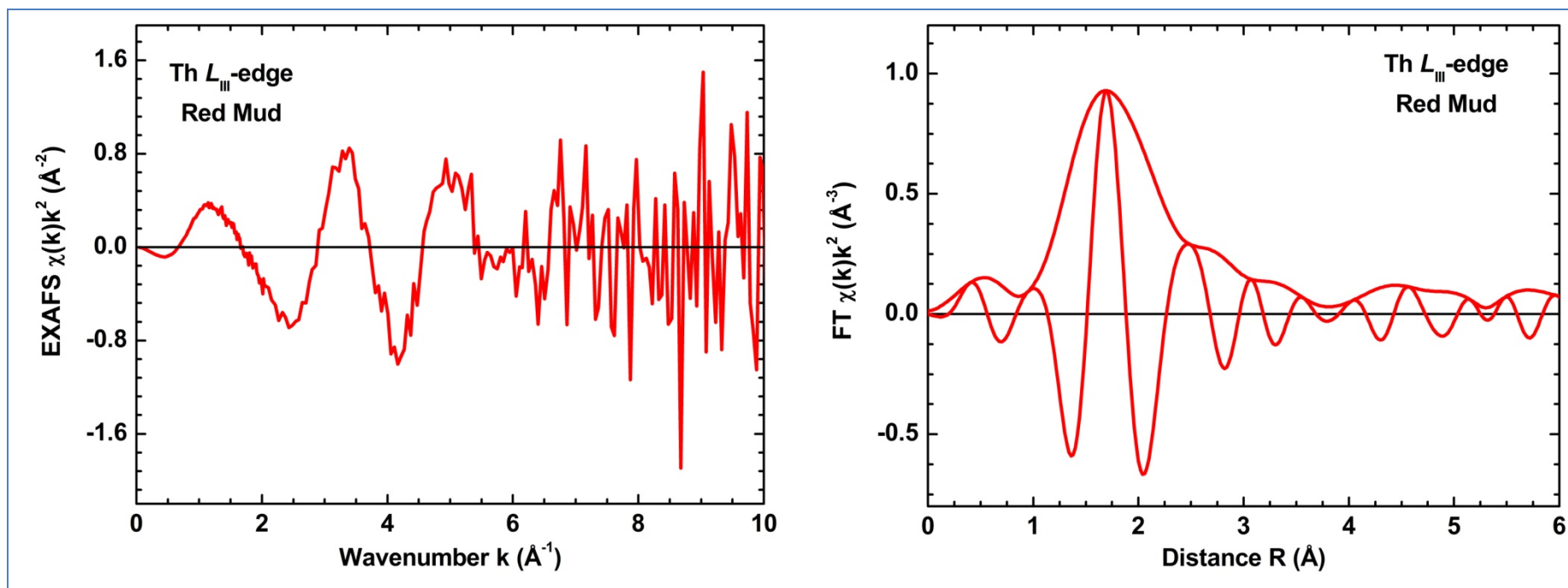
Supplementary Figure 11 | *Upper images*: HRTEM data, including a BF image and its SAED pattern (a), of a representative Ti-oxide particle (anatase / TiO_2), which exists in the “Al-Fe-Ca-Ti-Si-Na-Cr matrix” of the studied Greek bauxite residue / BR (red mud). The viewing direction for its SAED pattern is [111]. Several planar defects, common in anatase, can be observed in the HRTEM image (b). *Lower images*: STEM-HAADF images of the anatase, showing no apparent sign of Th. The HAADF contrast is proportional to the square of a mean atomic number.



Supplementary Figure 12 | BF image of the Th-free clay-like phases together with nano-perovskite (CTO) and Th-free Ti-containing hematite (Hem) co-existing into the “Al-Fe-Ca-Ti-Si-Na-Cr matrix” of the studied Greek bauxite residue / BR (red mud).



Supplementary Figure 13 | Th L_{III} -edge bulk XANES of the studied Greek bauxite residue / BR (red mud; present study) together with bulk & micro-XANES of Greek bauxite^{10,27}, compared with spectra of reference materials.



Supplementary Figure 14 | Experimental Th L_{III} -edge EXAFS spectrum (left image) and its Fourier transform – FT (right image) of the studied bauxite residue / BR (red mud).

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